Proceeding of the Electrical Engineering Computer Science and Informatics
Vol. 7, October 2020 ISSN: 2407-439X

Probabilistic Programming with Piecewise Objective Function for Solving Supplier Selection Problem with Price Discount and Probabilistic Demand

Sutrisno
Department of Mathematics
Diponegoro University
Semarang, Indonesia
s.sutrisno@live.undip.ac.id

Sunarsih
Department of Mathematics
Diponegoro University
Semarang, Indonesia
sunarsih@lecturer.undip.ac.id

Widowati
Department of Mathematics
Diponegoro University
Semarang, Indonesia
widowati@lecturer.undip.ac.id

***Abstract*—In this article, a supplier selection problem with price discount and probabilistic demand was solved by formulating a new probabilistic programming model with a piecewise objective function. The proposed model was able to be used by the decision-maker to calculate the optimal decision involving the appropriate raw material quantity to be ordered from each supplier to have minimal total procurement cost. A numerical experiment was conducted with some randomly generated data and the results showed the supplier selection problem was solved by the proposed model and the optimal decision value is achieved.**

***Keywords*—piecewise objective function, price discount, probabilistic demand, probabilistic programming, supplier selection**

I. INTRODUCTION

Industry actors in the manufacturing sector are continuously trying to use decision-making tools to reduce several operational cost components such as those associated with the purchase of raw materials in order to increase profit. Some of the raw materials needed by a manufacturer are usually purchased from several suppliers and this requires selecting the most fitted and beneficial. This phenomenon is known as the supplier selection problem and its mostly due to the fact that the suppliers have different characteristics, for example, the price they may vary. However, the consideration of only this parameter and omitting others makes it easy for manufacturers to decide on the supplier with the most beneficial attribute which is the cheapest price. Meanwhile, several cost components are attached to this problem and they include transport cost, raw material quality, supplier's service quality, supplier's capacity, and several others, thereby, making the decision-making tool necessary to purchase raw material.

Several industrial practitioners have used a mathematical optimization model as their decision-making tool mainly due to its ability to optimize an objective function such as cost function to produce an optimal decision. This approach was initially applied to supplier selection problem in [1], [2] through the use of a linear integer programming model and several advanced models have been developed afterwards by extending the approach to other areas such as network processes [3] - [8], the fuzzy concept [9] - [12], game theory [13], risk theory [14], and others. Moreover, each mathematical model has different attributes based on the problem they are meant to solve as observed in facility disruption [15], holding cost discount [16], deteriorating item scheme [17], [18], fast service scheme [19], and price break scheme [20]. For field application purposes, several articles have reported the methods used in solving supplier selection problem with some observed in industries such as automotive manufacturing [21], financial [22], power source [23] - [25], healthcare [26], [27], and others.

This article developed a decision-making tool to solve supplier selection problem using a probabilistic mathematical optimization model with the piecewise objective function. The term "probabilistic" was used to indicate the model's ability to deal with some probabilistic parameters in the problem such as the demand value. Meanwhile, "piecewise" was included to indicate the consideration of discount scheme in some price parameters such as the raw materials. Moreover, a numerical experiment was conducted in the laboratory scale to evaluate the formulated model and study the results.

II. METHODOLOGY

The methodology used in this research is described in this section followed by the proposed mathematical model.

A. Problem Definition

Consider a supplier selection problem with more than one supplier alternatives. Some amount of raw material will be purchased from these suppliers. This may involve more than one raw material type. Each supplier has its own attributes such us raw material price, maximum capacity (maximum available raw material to be purchased), etc. (see the mathematical model). The manufacturer wants to purchase the raw material needed to satisfy the demand while minimizing the total procurement cost. The raw material price, in this case, has discount where the discount scheme is modeled as a piecewise function. This means the price changes with the quantity ordered such that at high quantity, the price is cheaper (see the mathematical model for detailed explanation). Moreover, the demand value is uncertain that is approached as a random variable in this study.

B. Methodology

The methodology used in this study is illustrated by Fig. 1. According to Fig. 1, the first step in the methodology is defining the problem to be solved and declaring the assumptions to distinguish this study from others. Next, the deterministic and probabilistic parameters were identified with the probabilistic parameters observed to have required probability distribution function based on historical data. This was followed by the definition of the discount scheme on the raw material price as a piecewise objective function. Moreover, the expected total operational cost containing purchasing and penalty cost for defect raw material was defined as the main objective functions with due consideration for the piecewise function. The constraint functions to be held in the model were also formulated to include satisfying of demand, supplier's capacity, transportation capacity, and integer & non-negativity of the decision variable. The next step involved solving the optimization problem developed by generating random data which was later used for numerical experiment purposes. The final step was to interpret the optimal decision to be used by the decision-maker based on the optimization results.

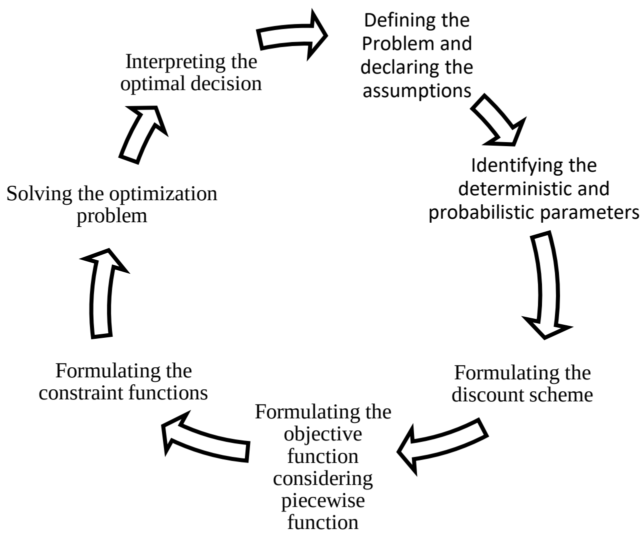

Fig. 1. Methodology of the problem-solving approach.

C. Assumptions and Notations

The mathematical model was formulated under the following assumptions:

1. There is a discount on the raw material price following a piecewise scheme and this means the price is cheaper for more volume or quantity purchased.
2. The quantity of the raw material is measured as an integer number.
3. It is possible there are some defects in the quantity ordered due to poor quality or damage and a financial loss called defect cost is usually attached.
4. There are two probabilistic parameters and they are the quantity of raw material demanded and the defect rate. The remaining parameters are known with certainty.
5. The raw material demanded is expected to be satisfied by those purchased.

These assumptions are then limit the mathematical model proposed in this study. Next, we introduce the mathematical notations used in the model as follow:

indices:

r : index of raw material type, $r \in \{1, 2, ..., R\}$;

s : index of supplier, $s \in \{1, 2, ..., S\}$;

i : index of price discount level, $i \in \{1, 2, ..., \hat{i}\}$;

decision variables:

$\mathrm{X}_{sr}^{(i)}$: A Special Ordered Set (SOS) decision variable representing the quantity (in unit) of the raw material type *r* ordered from supplier *s* at price discount level *i;*

TR_s : number of the delivery process from supplier *s*;

deterministic parameters:

$U_{sr}^{(i)}$: price for one unit of raw material type *r* at price discount level *i* ordered from supplier *s;*

TC_s : transportation cost for the one-time delivery process from supplier *s;*

$\hat{\mathrm{X}}_{sr}^{(i)}$: Bound of $\mathrm{X}_{sr}^{(i)}$ at price level *i;*

C_{sr} : capacity of supplier *s* to supply raw material type *r;*

TRC : maximum quantity of raw materials in one delivery loading;

DC_{sr} : penalty cost for one unit of a defect in raw material type *r* from supplier *s;*

DR_{sr} : defect rate of raw material type *r* from supplier *s;*

LC_{sr} : penalty cost for one unit of raw material type *r* delivered late by supplier *s;*

LR_{sr} : late delivery rate from supplier *s;*

probabilistic parameters:

D_r : random variable declaring the uncertain demand value of raw material *r.*

D. Mathematical Model

The discount for the unit price of one unit of raw material follows a linear piecewise function:

$$U_{sr} = \begin{cases} U_{sr}^{(1)}, & \text{if } \hat{\mathrm{X}}_{sr}^{(0)} \le \mathrm{X}_{sr}^{(i)} \le \hat{\mathrm{X}}_{sr}^{(1)}, \\ U_{sr}^{(2)}, & \text{if } \hat{\mathrm{X}}_{sr}^{(1)} < \mathrm{X}_{sr}^{(i)} \le \hat{\mathrm{X}}_{sr}^{(2)}, \\ \vdots & \\ U_{sr}^{(\hat{i})}, & \text{if } \hat{\mathrm{X}}_{sr}^{(\hat{i}-1)} < \mathrm{X}_{sr}^{(i)} \le \hat{\mathrm{X}}_{sr}^{(\hat{i})}. \end{cases} \quad (1)$$

The proposed model was formulated to minimize the total cost as follows:

$$
\begin{aligned}
\min Z = & \sum_{s=1}^{S}\sum_{r=1}^{R}\sum_{i=1}^{\hat{i}} U_{sr}^{(i)} \cdot X_{sr}^{(i)} + \sum_{s=1}^{S} TC_s \cdot TR_s \\
& + \sum_{s=1}^{S}\sum_{r=1}^{R}\left(DC_{sr} \cdot DR_{sr} \cdot \left(\sum_{i=1}^{\hat{i}} X_{sr}^{(i)} \right)\right) \\
& + \sum_{s=1}^{S}\sum_{r=1}^{R}\left(LC_{sr} \cdot LR_{sr} \cdot \left(\sum_{i=1}^{\hat{i}} X_{sr}^{(i)} \right)\right)
\end{aligned} \tag{2}
$$

subject to:

$$
\sum_{s=1}^{S}\left(\sum_{i=1}^{\hat{i}} X_{sr}^{(i)} - DR_{sr} \cdot \sum_{i=1}^{\hat{i}} X_{sr}^{(i)} - LR_{sr} \sum_{i=1}^{\hat{i}} X_{sr}^{(i)} \right) \geq D_r, \quad \forall r = 1,2,...,R; \tag{3}
$$

$$
\left\lceil \frac{\sum_{r=1}^{R}\sum_{i=1}^{\hat{i}} X_{sr}^{(i)}}{TRC} \right\rceil \leq TR_s, \ \forall s = 1,2,...,S; \tag{4}
$$

$$
\sum_{i=1}^{\hat{i}} X_{sr}^{(i)} \leq C_{sr}, \quad \forall s = 1,2,...,S, \ \forall r = 1,2,...,R; \tag{5}
$$

$$
\{X_{sr}^{(i)}, i = 1,...,\hat{i}\} \text{ is a Special Ordered Set (SOS);} \tag{6}
$$

$$
\begin{aligned}
& X_{sr}^{(i)}, TR_s \in \{0,1,2,...\}, \ \forall s = 1,2,...,S, \\
& \forall r = 1,2,...,R \ \forall i = 1,2,...,\hat{i}.
\end{aligned} \tag{7}
$$

Note that decision variable $X_{sr}^{(i)}, i = 1,...,\hat{i}$ is a SOS variable for any s and r. With this SOS variable, at most, only one variable from set $X_{sr}^{(i)}, i = 1,...,\hat{i}$ will be greater than 0.

In the objective function(2), the first term presents the total purchasing cost, the second indicates the total transportation cost, and the third shows the expected defect cost for the whole raw material from all suppliers. The constraint functions (3) show the raw materials purchased from all suppliers minus the quantity of defect ones is expected to satisfy the demand value. Constraint (4) means that the number of delivery loading is also expected not to exceed the number of transportation available where $\lceil . \rceil$ denotes the ceil function whereas constraint (5) means that the quantity of the raw materials ordered from the supplier is not expected to exceed the supplier's maximum capacity to supply the corresponding raw material. Constraint (6) explains that the decision variable $X_{sr}^{(i)}, i = 1,...,\hat{i}$ is a SOS, and the constraint (7) used to assign the integer and non-negative value for the decision variables.

In stochastic optimization theory, the optimization problem (2) is a model to determine the wait-and-see solution and this means the decision is executed after the random variable has been revealed. In this case, the quantity of the raw material ordered is expected to be executed right after the demand value has been revealed using the computational process which involves the generation of the random parameter through the use of some probability distribution functions.

III. Numerical Experiment

A simulation experiment was conducted in the laboratory to evaluate the proposed mathematical model using a daily used personal computer with a 2.6 GHz processor, 4 GB RAM, and Windows 10 operating system. The optimization problem was calculated in LINGO 18.0 software using the generalized reduced gradient method combined with the branch and bound algorithm to determine the integer solution.

A. Problem Setup

The data used in the simulation were generated randomly and the problem had four supplier alternatives denoted by S1, S2, S3, and S4, four raw material types indicated by R1, R2, R3, and R4, and three discount levels on the unit price represented by discount level D1, D2, and D3. The demand value was random and assumed to be normally distributed with 20 units of mean and 10 units of variance.

The demand data was generated with only four scenarios due to the computational time limit as shown in Table 1. The demand value for raw material R4 at scenario 1 is then manually made to be zero to see how the solution is produced by the proposed decision-making model. Meanwhile, the unit price for the raw material price with the discount scheme used as a piecewise linear function (1) was rewritten as

$$
U_{sr} = \begin{cases} U_{sr}^{(1)}, & \text{if } \ 0 \leq X_{sr} \leq 10, \\ U_{sr}^{(2)}, & \text{if } \ 10 < X_{sr} \leq 20, \\ U_{sr}^{(3)}, & \text{if } \ 20 < X_{sr} \leq C_{sr}. \end{cases} \tag{8}
$$

Where the values for $U_{sr}^{(i)}$ are presented in Table 2 and those for the remaining parameters shown in Table 3 to 7. The simulation results are, therefore, indicated in Fig. 2 to 5.

TABLE I. Generated Demand Value with Four Scenarios

Scenario	Raw Material			
	R1	***R2***	***R3***	***R4***
1	11	26	26	0
2	29	38	35	39
3	24	15	16	18
4	16	10	9	20

TABLE II. Unit Raw Material Price with Three Discount Levels

Supplier	Raw Material					
	R1			***R2***		
	D1	***D2***	***D3***	***D1***	***D2***	***D3***
S1	10	9.5	9	20	19	19
S2	10	9	9	21	20.5	20
S3	11	10	9	20	20	19
S4	10	10	9	20	20	18

TABLE III. UNIT RAW MATERIAL PRICE WITH THREE DISCOUNT LEVELS

Supplier	Raw Material					
	R3			*R4*		
	D1	*D2*	*D3*	*D1*	*D2*	*D3*
S1	50	48	48	50	48	49
S2	52	50	48	50	48	48
S3	50	48	48	50	48	48
S4	50	50	47	51	49	48

TABLE IV. PENALTY COST PARAMETERS

Parameter	Raw Material			
	R1	*R2*	*R3*	*R4*
Defect penalty cost per unit of raw material	0.5	1	1	2
Delay penalty cost per unit of raw material	0.2	0.5	0.5	1

TABLE V. DELAY RATE OF RAW MATERIAL

Supplier	Raw Material			
	R1	*R2*	*R3*	*R4*
S1	0.02	0.02	0.02	0.02
S2	0.02	0.00	0.02	0.01
S3	0.01	0.01	0.03	0.02
S4	0.02	0.02	0.02	0.00

TABLE VI. DEFECT RATE OF RAW MATERIAL

Supplier	Raw Material			
	R1	*R2*	*R3*	*R4*
S1	0.01	0.02	0.04	0.03
S2	0.00	0.01	0.05	0.02
S3	0.02	0.00	0.05	0.03
S4	0.02	0.02	0.02	0.04

TABLE VII. MAXIMUM CAPACITY OF SUPPLIER

Supplier	Raw Material			
	R1	*R2*	*R3*	*R4*
S1	40	20	10	20
S2	20	10	15	10
S3	30	30	20	15
S4	20	40	10	25

B. *Results*

Fig. 2 to 5 shows the optimal decision for each scenario of the demand value derived from solving the optimization(2) . Due to the computational time limitation, the process was interrupted after 3.5 hours and a suboptimal solution was derived as shown in Fig. 1. It is possible for the decision-maker to stop the process in case there is no time to complete the computation.

For scenario 1 which involves the demand value following the first line in Table 1, the optimal decision was to order 12 units of raw material R1 from supplier S2, 28 of R2 from S4, as well as 10, 8, and 10 units of R3 from S1, S2, and S4 respectively without ordering any unit of R4. Moreover, the optimal decision for scenarios 2 to 4 was drawn analogously with the total cost for scenario 1 to 4 being 2128.168, 4967.254, 2408.126, and 2012.128 respectively. The actual decision that will be executed by the decision-maker is then one of these four scenarios following which scenario is revealed. This is the limitation of this wait-and-see approach where the optimal decision is applied after all uncertain parameters are known.

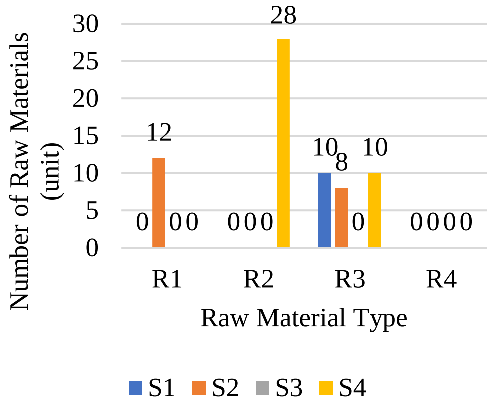

Fig. 2. The optimal amount of raw material ordered to the suppliers for scenario 1 solution.

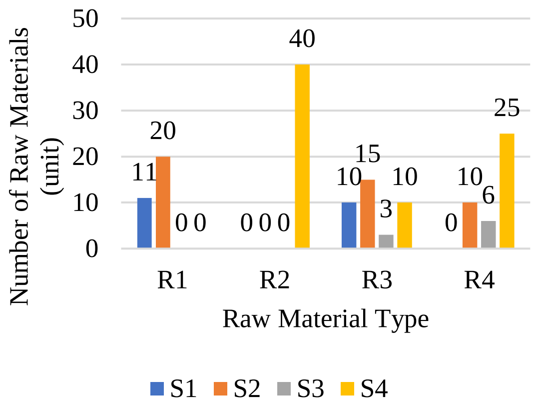

Fig. 3. The optimal amount of raw material ordered to the supplier for scenario 2 solution.

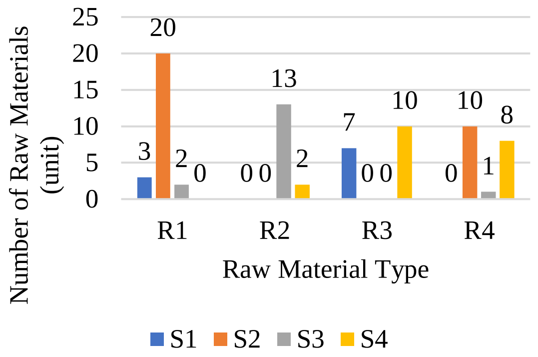

Fig. 4. The optimal amount of raw material ordered to the supplier for scenario 3 solution.

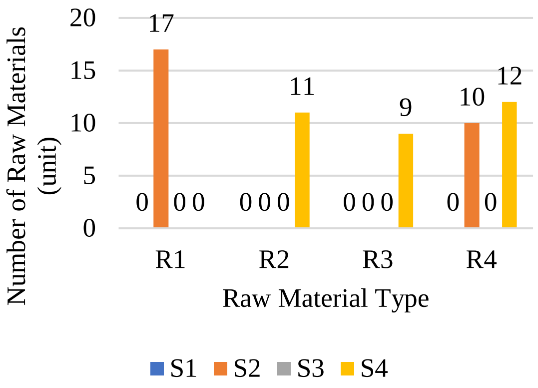

Fig. 5. The optimal amount of raw material ordered to the supplier for scenario 4 solution.

C. *Discussion and Analysis*

From the optimal decision shown in Fig. 2 to 5, it can be seen that the purchasing amount was a bit more than the demand in order to response the possibility of rejected and late delivered items. For example, at scenario 1 the purchased raw material R1 was 12 units where 10 units of them was used to satisfy the demand the other 2 units was not received due to defected by the manufacturer or late delivered by the supplier. A special case was occurred where no raw material R4 were purchased from any supplier and this makes sense as a response to zero demand value for this raw material type.

The price discount analysis is following. To each supplier, the raw material was purchased at a certain discount level. For example, at scenario 2 the manufacturer purchases raw material R1 to supplier S1 at the second discount level with price 9.5 per unit as well as to supplier S2 with price 9 per unit. These all items of raw material R1 were not purchased to one supplier because of that decision may need more money to expend. A different decision was made for raw material R2 where the manufacturer bought 40 items all from supplier S4 at discount level D3 with price 18 per unit. In this case, purchasing from more than one supplier may need more money to expend.

These results show that the proposed decision-making tool was able to find the optimal decision under the conditions faced in the problem. Further verification for the optimal decision derived by the proposed model is discussed by comparing with other similar studies as follows. Thousands of papers related to supplier selection problem are available in the literature. Each paper has its own characteristics on the problem discussed in the paper. Four papers providing supplier selection with discount level were chosen as they are very similar to the proposed model studied in this paper. We have claimed that the proposed model was able to find the optimal decision as illustrated in Fig. 2 to 5. The similar results were shown by the optimal decision on: Fig. 6 and 7 in [28], a discussion on Section 4.3 in [29], Table 16 in [30], and a discussion on Section 4 in [31], where the optimal quantities of raw material/product were derived and it was following the discount scheme defined on the mathematical model. Furthermore, all of these approaches including the proposed model in this paper were derived the optimal decision under the uncertainty, in this case, under probabilistic demand condition.

IV. Conclusions and Future Works

A mathematical optimization model was developed to solve a supplier selection problem with probabilistic demand and consideration for price discount which was handled using a piecewise function on the objective cost. This model was further simulated with randomly generated data and the optimal decision was produced for the problem. The proposed model was able to decide the best discount level and was calculated the optimal decision with uncertain demand value via wait-and-see solution approach.

In a case where the decision-maker wants to executed the decision before the uncertain parameters are revealed, further research is needed to obtain the decision under uncertain conditions such that it is executed before the random variable is known. This is interesting to be studied via e.g. advanced stochastic programming methods. More complex problems are also interesting to study such as cases for multi-period of time, carrier presence, and several others.

Acknowledgement

The authors appreciate the Faculty of Science and Mathematics, Diponegoro University for providing research funding under the DPA FSM UNDIP 2020 grant.

References

[1] N. R. Ware, S. P. Singh, and D. K. Banwet, "Expert Systems with Applications A mixed-integer non-linear program to model dynamic supplier selection problem," *Expert Syst. Appl.*, vol. 41, no. 2, pp. 671–678, 2014.

[2] F. M. P. Raupp, M. M. Monteiro, and J. E. Leal, "A four-type decision-variable MINLP model for a supply chain network design," *Math. Probl. Eng.*, vol. 2010, 2010.

[3] S. S. Kara, "Expert Systems with Applications Supplier selection with an integrated methodology in unknown environment," *Expert Syst. Appl.*, vol. 38, no. 3, pp. 2133–2139, 2011.

[4] Z. Li, W. K. Wong, and C. K. Kwong, "An Integrated Model of Material Supplier Selection and Order Allocation Using Fuzzy Extended AHP and Multiobjective Programming," *Math. Probl. Eng.*, vol. 2013, pp. 1–14, 2013.

[5] M. Abbasi, R. Hosnavi, and B. Tabrizi, "An Integrated Structure for Supplier Selection and Configuration of Knowledge-Based Networks Using QFD, ANP, and Mixed-Integer Programming Model," *J. Ind. Eng.*, vol. 2013, pp. 1–8, 2013.

[6] M. Zeydan, C. Çolpan, and C. Çobanoğlu, "A combined methodology for supplier selection and performance evaluation," *Expert Syst. Appl.*, vol. 38, no. 3, pp. 2741–2751, 2011.

[7] W. Pan, F. Wang, Y. Guo, and S. Liu, "A Fuzzy Multiobjective Model for Supplier Selection under Considering Stochastic Demand in a Supply Chain," *Math. Probl. Eng.*, vol. 2015, pp. 1–8, 2015.

[8] G. K. Kumar, M. S. Rao, and V. V. S. K. Rao, "Supplier Selection and Order Allocation in Supply Chain," *Mater. Today Proc.*, vol. 5, no. 5, pp. 12161–12173, 2018.

[9] M. Izadikhah, "Group Decision Making Process for Supplier Selection with TOPSIS Method under Interval-Valued Intuitionistic Fuzzy Numbers," *Adv. Fuzzy Syst.*, vol. 2012, pp. 1–14, 2012.

[10] Sutrisno, Widowati, and R. H. Tjahjana, "Fuzzy Expected Value Based Model to Solve Integrated Supplier Selection and Inventory Control Problem in Fuzzy Environment," *Int. J. Supply Chain Manag.*, vol. 7, no. 3, pp. 24–30, 2018.

[11] Sutrisno, Widowati, Sunarsih, and Kartono, "Expected value based fuzzy programming approach to solve integrated supplier selection and inventory control problem with fuzzy demand," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 300, no. 012009, pp. 1–8, 2018.

[12] C.-M. Wu, C.-L. Hsieh, and K.-L. Chang, "A Hybrid Multiple Criteria Decision Making Model for Supplier Selection," *Math. Probl. Eng.*, vol. 2013, pp. 1–8, 2013.

[13] M. Esmaeili and S. N. Ghobadi, "A game theory model for pricing and supplier selection in a closed-loop supply chain," *Int. J. Procure. Manag.*, vol. 11, no. 4, pp. 472–494, Jan. 2018.

[14] M. Bahroun, S. Harbi, and H. Bouchriha, "A new approach for ordering decision under uncertainties: a case study in the retail supply chain," *Int. J. Logist. Syst. Manag.*, vol. 32, no. 3–4, pp. 392–413, Jan. 2019.

[15] M. Rafiei, M. Mohammadi, and S. A. Torabi, "Reliable multi period multi product supply chain design with facility disruption," *Decis. Sci. Lett.*, vol. 2, no. 2, pp. 81–94, 2013.

[16] Sutrisno, Widowati, and D. A. Munawwaroh, "Hybrid mathematical model of inventory system with piecewise holding cost and its optimal strategy," *ICAMIMIA 2015 - Int. Conf. Adv. Mechatronics, Intell. Manuf. Ind. Autom. Proceeding - conjunction with Ind. Mechatronics Autom. Exhib. IMAE*, pp. 29–33, 2015.

[17] M. Rastogi and S. R. Singh, "A production inventory model for deteriorating products with selling price dependent consumption rate and shortages under inflationary environment," *Int. J. Procure. Manag.*, vol. 11, no. 1, p. 36, 2018.

[18] A. S. Yadav and A. Swami, "Integrated supply chain model for deteriorating items with linear stock dependent demand under imprecise and inflationary environment," *Int. J. Procure. Manag.*, vol. 11, no. 6, pp. 684–704, Jan. 2018.

[19] M. Alegoz and H. Yapicioglu, "Supplier selection and order allocation decisions under quantity discount and fast service options," *Sustain. Prod. Consum.*, vol. 18, pp. 179–189, Apr. 2019.

[20] L. Duan and J. A. Ventura, "A Dynamic Supplier Selection and Inventory Management Model for a Serial Supply Chain with a Novel Supplier Price Break Scheme and Flexible Time Periods," *Eur. J. Oper. Res.*, vol. 272, no. 3, pp. 979–998, 2019.

[21] N. Jamil, R. Besar, and H. K. Sim, "A Study of Multicriteria Decision Making for Supplier Selection in Automotive Industry," *J. Ind. Eng.*, vol. 2013, no. September 2008, pp. 1–22, 2013.

[22] S. Onut and S. Tosun, "An Integrated Methodology for Supplier Selection under the Presence of Vagueness: A Case in Banking Sector, Turkey," *J. Appl. Math.*, vol. 2014, pp. 1–14, 2014.

[23] Z. Tan, L. Ju, X. Yu, H. Zhang, and C. Yu, "Selection Ideal Coal Suppliers of Thermal Power Plants Using the Matter-Element Extension Model with Integrated Empowerment Method for Sustainability," *Math. Probl. Eng.*, vol. 2014, pp. 1–11, 2014.

[24] C.-W. Tsui and U.-P. Wen, "A Hybrid Multiple Criteria Group Decision-Making Approach for Green Supplier Selection in the TFT-LCD Industry," *Math. Probl. Eng.*, vol. 2014, pp. 1–13, 2014.

[25] M. B. Alam, R. Pulkki, C. Shahi, and T. P. Upadhyay, "Economic Analysis of Biomass Supply Chains: A Case Study of Four Competing Bioenergy Power Plants in Northwestern Ontario," *ISRN Renew. Energy*, vol. 2012, pp. 1–12, 2012.

[26] M. Fazli-Khalaf and N. G. Nemati, "A socially responsible supplier selection model under uncertainty: case study of pharmaceutical department of an Iranian hospital," *Int. J. Logist. Syst. Manag.*, vol. 32, no. 1, pp. 69–90, Dec. 2018.

[27] M. Kumar and D. Kumar, "Green logistics decision support system for blood distribution in time window," *Int. J. Logist. Syst. Manag.*, vol. 31, no. 3, pp. 420–447, Jan. 2018.

[28] T. Kirschstein and F. Meisel, "A multi-period multi-commodity lot-sizing problem with supplier selection , storage selection and discounts for the process industry," *Eur. J. Oper. Res.*, vol. 279, no. 2, pp. 393–406, 2019.

[29] M. Safaeian, A. M. Fathollahi-fard, and G. Tian, "A multi-objective supplier selection and order allocation through incremental discount in a fuzzy environment," *J. Intell. Fuzzy Syst.*, vol. 37, no. 1, pp. 1435–1455, 2019.

[30] S. Hamdan and A. Cheaitou, "Computers & Industrial Engineering Dynamic green supplier selection and order allocation with quantity discounts and varying supplier availability," *Comput. Ind. Eng.*, vol. 110, pp. 573–589, 2017.

[31] H. K. Alfares and R. Turnadi, " vol. 116, no. August 2017, pp. 59–71, 2018.